

DRAFT

The PHOTON PBL Project

PBL Challenge Implementation Guide

6/23/09

PHOTON PBL Challenge Implementation Flow Chart

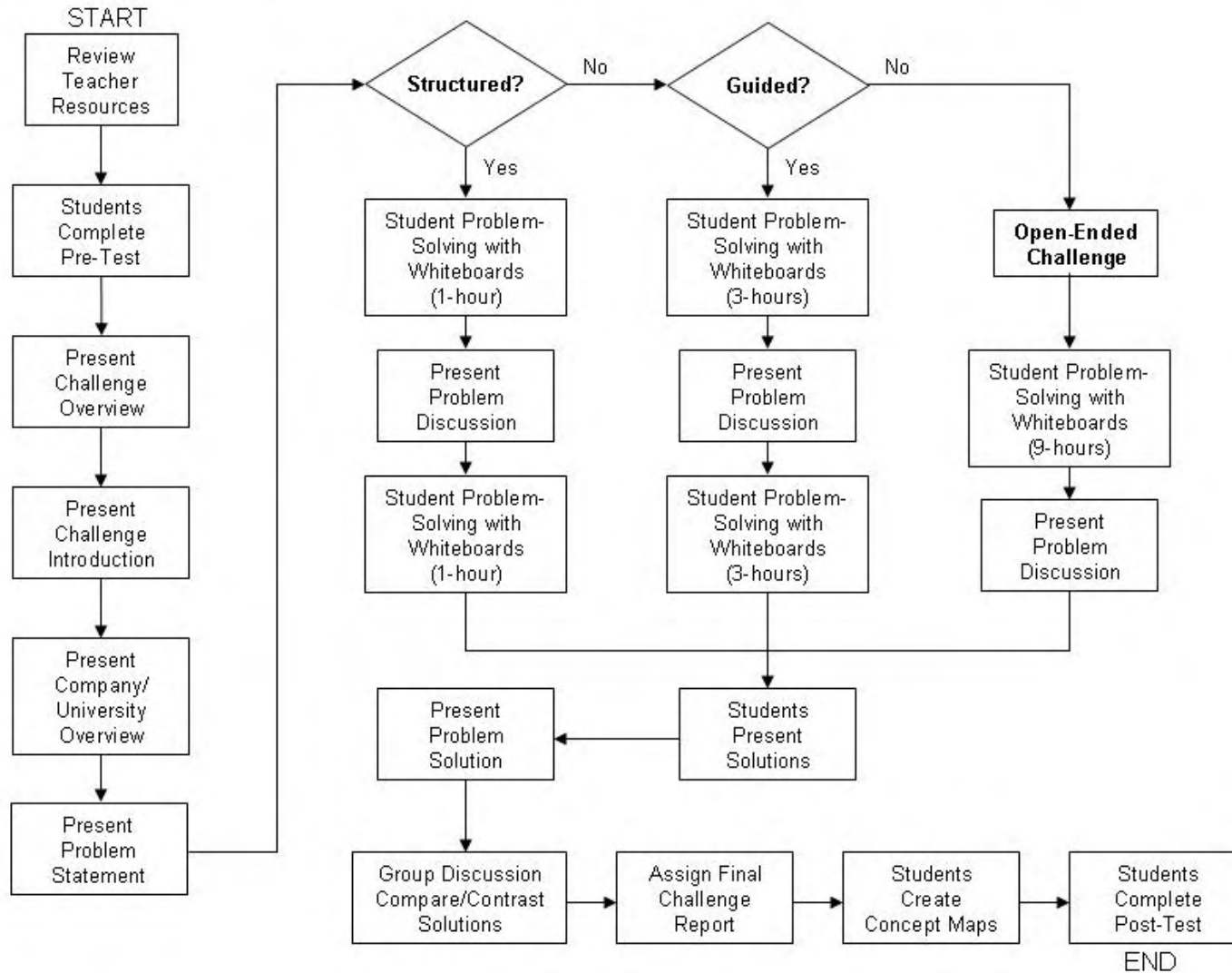


Figure 1 – PHOTON PBL Implementation Flow Chart

**The PHOTON PBL Project
PBL Challenge
Implementation Instructions**

I. The PHOTON PBL Challenges

The PHOTON PBL challenges are located at the following website:

<http://pblprojects.org>

PBL Challenge Main Pages

Each PHOTON PBL Challenge contains six main pages:

- 1) Challenge Overview
- 2) Introduction
- 3) Company/University Overview
- 4) Problem Statement
- 5) Problem Discussion
- 6) Problem Solution

Table 1 provides a description of each PBL Challenge page. The PBL Challenge site map is shown in Figure 2.

PBL Challenge Resource Pages

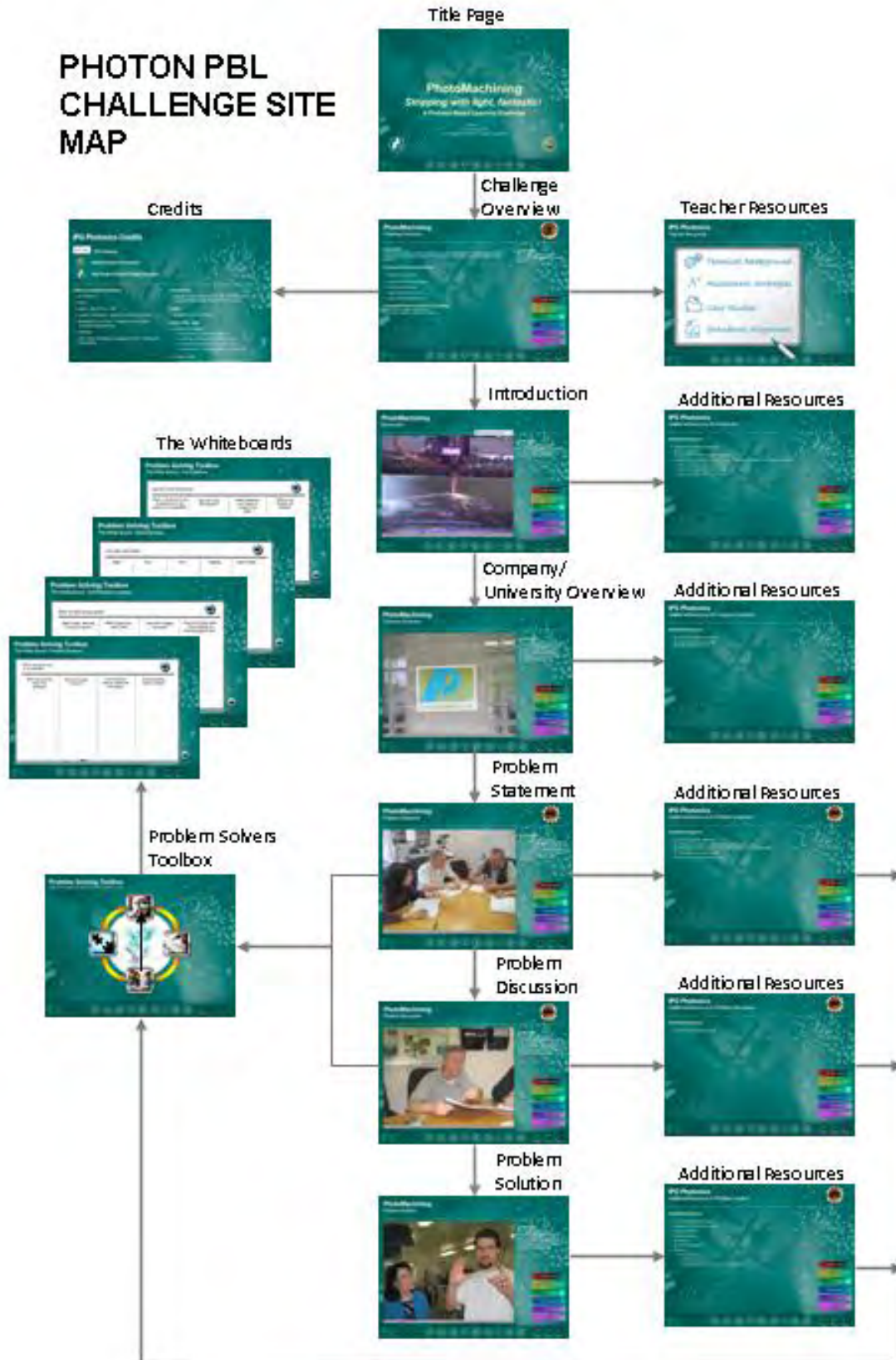
Each PHOTON PBL Challenge contains instructional resources for teachers and problem-solving resources for students:

- 1) **Teacher Resources: *Password-Protected Link on Challenge Overview Page****
 - a. Technical Background
 - b. Assessment Strategies
 - c. Implementation Stories
 - d. Standards Alignment

- 2) **Student Resources: *Link on Problem Statement and Problem Discussion Pages***
 - a. Problem Solving Toolbox
 - b. The Whiteboards
 - c. Additional Resources

Table 2 provides a description of the Problem Solving Toolbox.

**** Passwords located in the appendix.***



II. Implementation Instructions

The Photon PBL Challenges employ a three-level scaffolded design to “ease” students into the PBL instructional method. The three levels range from Structured (Instructor Led), to Guided (Instructor Guided), to Open-Ended (Instructor as Consultant) depending on the technical nature of the problem and the ability level of the students. Each of the Photon PBL Challenges contains **password-protected** sections to allow instructors control of the format (Structured, Guided or Open-Ended) and pace of instruction (see attached for PBL Challenge passwords). In general, students who are new to the PBL challenges should begin using the structured approach, then progress to the guided approach, and finally the open-ended approach once they are comfortable with the PBL process

Prior to introducing the PBL Challenge, review the technical overview located in the password-protected **Teacher Resources** section of the challenge to acquaint you with the problem situation, the technical principles reinforced, and the problem solution.

While institutions may vary in how course time is scheduled, the following implementation recommendations are based on one 3-hour time block per week to conform to the traditional 3-hour weekly lab session.

A. **Structured Challenge (Instructor Led):**

Estimated Time for Completion: One 3-hour class + 1-hour follow-up

Used for students with no PBL experience and/or limited technical background. This approach is essentially an interactive multimedia case study. A structured challenge can be introduced in one 3-hour lab period with follow up review during the next class.

STEPS:

1. ***Class I:*** Present **Challenge Overview** and review additional resources with students
2. Present **Introduction** video and review additional resources with students
3. Present **Company/University Overview** video and review additional resources with students
4. Present **Problem Statement** video and review additional resources with students
5. Explain the **Problem Solvers Toolbox** and introduce the **Whiteboards**. Guide students in completing each of the Whiteboards to frame the problem. Allow time for initial internet research and brainstorming ideas (Approximately 1-hour).
6. Present the **Problem Discussion** to the class and provide them with the Problem Discussion password (PD #####) so that they can seek out additional information. Continue group problem solving session using the Whiteboards, filling in missing information. Provide students with additional time to continue Internet research and brainstorm possible solutions (Approximately 1-hour).
7. **Student Presentations:** Have students present their solutions in an informal presentation and describe the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).

DRAFT

8. Present the **Problem Solution** video to the class and provide them with Problem Solution password (PS ####) so that they can review the solution on their own. Conduct a group discussion to compare and contrast solutions (Approximately 30 minutes).
9. Assign students the **Final Challenge Report** to be completed as a homework assignment. Provide them with the **Final Challenge Report Scoring Rubric** to guide their report preparation.
10. **Class II:** Break students into small groups (3-4 students) and have them create a **Concept Map** for the challenge (concept mapping instructions provided; approximately 1-hour or assign for homework). Provide students with Concept Map Scoring Rubric to guide their work.

B. Guided Challenge (Instructor Guided):

Estimated Time for Completion: Two 3-hour classes + 1-hour follow-up)

Once introduced to the PBL process using the structured approach, students can progress to the guided approach. The guided approach is similar to structured approach, but student groups are allowed to work with limited instructor supervision and are provided more time to develop a more complete solution. The instructor acts as a facilitator to ensure that students stay on track, but refrains from providing solutions or answers to specific questions. This strategy is intended to further develop students' ability to think critically by allowing them to actively engage in the problem-solving process, but at the same time providing a safety net so that learning occurs without risk of failure.

STEPS:

1. **Class 1:** Repeat **Structured Challenge Steps 1-4**. Have students complete the Whiteboards as done previously. Reiterate that it is **extremely important** to be as thorough as possible when completing the Whiteboards.
2. **Class II:** Present **Problem Discussion** to the class and provide students with the Problem Discussion password (PD ####). Allow students to continue working on their problem solutions. Continue to provide guidance as needed, but limit your input to guiding questions instead of simply providing answers. At this point students should be well on their way to converging on their solution and test plan and should begin putting together their solution presentation.
3. **Class III: Student Presentations:** Have students present their solutions in a formal PPT presentation. As in the structured approach, students should describe the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).
4. Repeat **Structured Approach Steps 8-10**.

C. Open-Ended Challenge (Instructor as Consultant):

Estimated Time for Completion: Three 3-hour classes + 1 hour follow-up

In the open-ended approach, students are presented with the most realistic representation of the problem as it would be encountered in the real world. In the open-ended approach, students are provided only with information from the **Introduction, Company/University Overview, and Problem Statement**, and are tasked with researching and developing their own solutions without the benefit of the **Problem Discussion**. Drawing on the problem-solving skills

DRAFT

developed through engagement in the structured and guided approaches, students complete the Whiteboards with minimal guidance. During this process, the instructor acts as a consultant, providing hints or clues on request, but for a price (e.g., points deducted from a mock budget). Only after the student solutions have been presented in a mock design review are the Problem Discussion and Problem Solution revealed. Student solutions are then compared and contrasted with the industry/university solutions in a group discussion and recommendations for improvements are discussed.

STEPS:

1. **Class I:** Repeat **Structured Challenge Steps 1-4**. Reiterate the **importance** of being as thorough as possible when completing the Whiteboards. Allow 2-3 complete class periods (3-6 hours) for students to work through the Whiteboards, conduct research, and develop their solutions and test plans. Instruct students to make sure they budget enough time for their work.
2. **Class II & III:** Allow student to continue working on their solutions while providing guidance and feedback upon request. Continue to provide guidance as needed, but limit your input to guiding questions instead of simply providing answers.
3. **Class IV: Student Presentations:** Have students present their solutions in a formal PPT presentation. As in the structured approach and guided approach, students should describe in detail the process (referring to the Whiteboards) they used to solve the problem (Approximately 30 minutes).
4. Repeat **Structured Approach Steps 8-10**.

III. Assessment

The PHOTON PBL Challenges include three student assessment measures: (1) Content knowledge, (2) conceptual knowledge, and (3) problem-solving ability. Instruction for each of these assessment measures are located in the Teacher Resource section of each challenge and are password protected. A summary of each measure is as follows:

Content Knowledge

A test bank consisting of multiple choice questions pertaining to technical content associated with each challenge is available in the Teacher Resources section of the challenge. We recommend that pre-post testing be conducted with each challenge introduced to provide a measure of improvement in content knowledge associated with each challenge.

Conceptual Knowledge

Conceptual knowledge is assessed through concept mapping. Each challenge contains a list of main concepts, a reference concept map (for instructors), detailed instructions for students on how to construct a concept map, and a concept map scoring rubric. We recommend that upon completion of the first structured challenge, instructors introduce the process of concept mapping using a simple topic (included in the instructions) to ensure students understand the structure and process for creating a concept map and how they will be assessed (provide students with the scoring rubric). Once students are clear on how to construct a concept map and how they will be assessed, assign the concept map exercise

for the particular challenge, and allow students to work on it with their team and complete it for homework.

Problem Solving Ability

Problem solving ability is assessed using the Final Challenge Report, which provides a summary the problem solving process engaged in by students, a synthesis of the knowledge, skills and strategies employed in solving the challenge, and the reflective judgment used in the students’ post-challenge assessment of their solution. We recommend that the Final Challenge Report be assigned after completion of the students’ solution presentation, but before the concept mapping exercise. The assessment sequence is illustrated in Figure 3.



Figure 3 – Assessment Sequence

Calculating Student Grade

Total Score

Total score is calculated using a weighted sum of content knowledge (C), conceptual knowledge (K), and problem solving ability (P):

$$\text{Total Score} = w_1 \cdot (C) + w_2 \cdot (K) + w_3 \cdot (P)$$

where w_1 , w_2 , and w_3 are weighting factors determined by the instructor. This is illustrated below in Figure 4. Detailed instructions and resources for assessing content knowledge, conceptual knowledge, and problem solving ability can be found in the **Teacher Resources** section of each Challenge under *Assessment Strategies*.

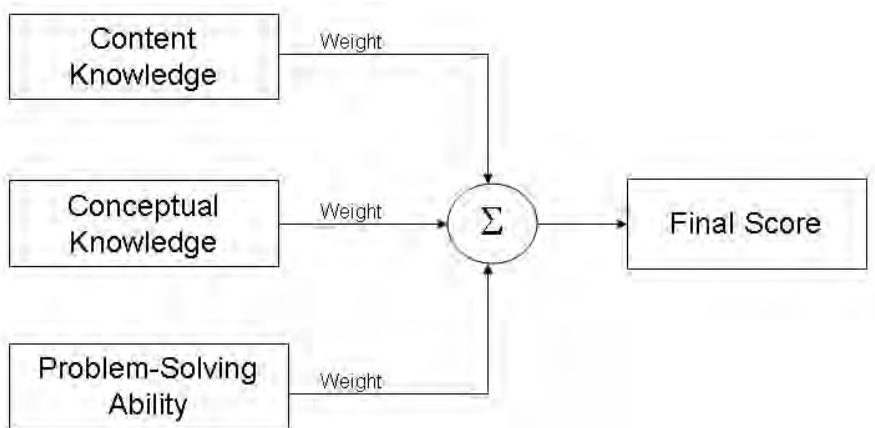


Figure 4 – Student Assessment in PBL

Table 1 - PHOTON PBL Challenge Main Challenge Pages





<p>Challenge Page 1</p> <p>PBL Challenge Front Page</p>	
<p>Challenge Page 2</p> <p>PBL Challenge Overview</p> <p>This page provides a brief description of the challenge, the photonics principles reinforced, a portal leading to the Teacher Resource page, and an array of buttons for accessing the different segments of the challenge which appear on each proceeding slide</p>	
<p>Challenge Page 3</p> <p>PBL Challenge Introduction</p> <p>This page provides a multimedia introduction to the technology being addressed in the challenge.</p>	
<p>Challenge Page 4</p> <p>Company/University Overview</p> <p>This page provides a multimedia tour of the company or university lab to provide the student with a brief overview of the context in which the problem was solved.</p>	

Table 1 - PHOTON PBL Main Challenge Pages - Continued




<p style="text-align: center;">Challenge Page 5</p> <p style="text-align: center;">Problem Statement</p> <p>This page provides a multimedia re-enactment of the problem as it was originally tour of the company or university lab to provide the student with a brief overview of the context in which the problem was solved.</p>	
<p style="text-align: center;">Challenge Page 6</p> <p style="text-align: center;">Problem Discussion</p> <p>This password-protected page provides a multimedia re-enactment of the brainstorming session conducted by the technical personnel who originally solved the problem. The purpose is to provide students with “hints” as to how the original team approached to problem to help guide the students in their problem solving session. The password is provided by the instructor at a point in the challenge activity when students conclude that more information is needed to solve the problem.</p>	
<p style="text-align: center;">Challenge Page 8</p> <p style="text-align: center;">Problem Solution</p> <p>This password-protected page provides a multimedia presentation of the actual problem solution developed by the company or university research lab. Each challenge contains detailed technical resources and tutorials that clearly explain the solution and provide thought-provoking questions designed to explore further key concepts and principles.</p>	

Table 2 - PHOTON PBL Problem Solving Toolbox


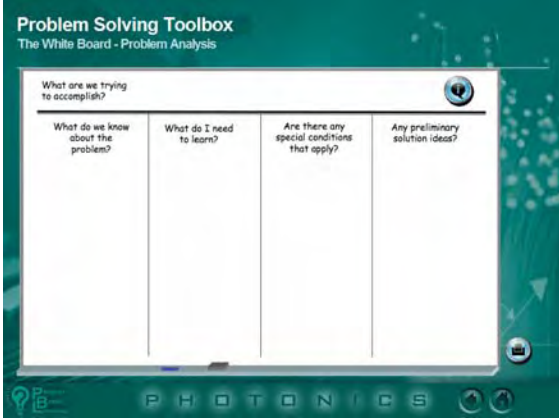
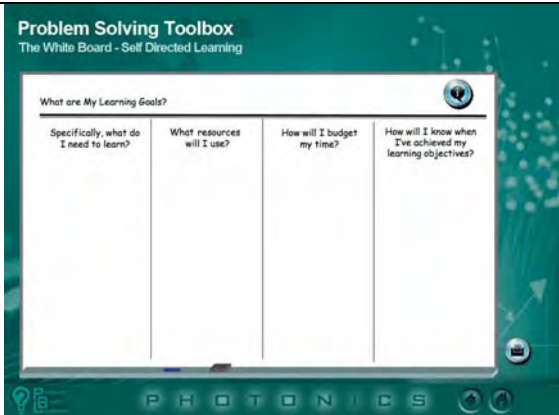
<p>Problem Solving Toolbox Slide 1</p> <p style="text-align: center;">The Problem Solving Cycle</p> <p>The problem solving toolbox is designed to help students develop a systematic method for solving ill-structured problems. Problem solving is a recursive process involving four main steps: (1) Problem analysis, (2) self-directed learning, (3) brainstorming, and (4) testing your solution. Clicking on any of the four icons will bring you to the “Whiteboards.” The whiteboards can be projected onto an actual classroom whiteboard to help instructors facilitate the problem-solving process.</p>	
<p>Problem Solving Toolbox Slide 2</p> <p style="text-align: center;">The Problem-Analysis Whiteboard</p> <p>The Problem Analysis Whiteboard is a tool for helping students clearly and accurately define and frame the problem. The whiteboard assists students in developing a clear understanding of the desired outcome, identifying what information is known, what information needed, and any special conditions that may apply. Only when students have clearly and accurately defined these parameters can they develop an effective plan for action. At this point, any preliminary solution ideas may be proposed a solution to help guide the process.</p>	
<p>Problem Solving Toolbox Slide 3</p> <p style="text-align: center;">The Self-Directed Learning Whiteboard</p> <p>The Self-Directed Learning whiteboard is a tool designed to help students take responsibility for acquiring the knowledge and skills identified in the problem analysis phase through goal setting and resource management. Self-directed learning includes setting specific learning goals, identifying the necessary information and resources, self-testing knowledge and comprehension, and evaluating the effectiveness of specific learning strategies.</p>	

Table 2 - PHOTON PBL Problem Solving Toolbox - Continued

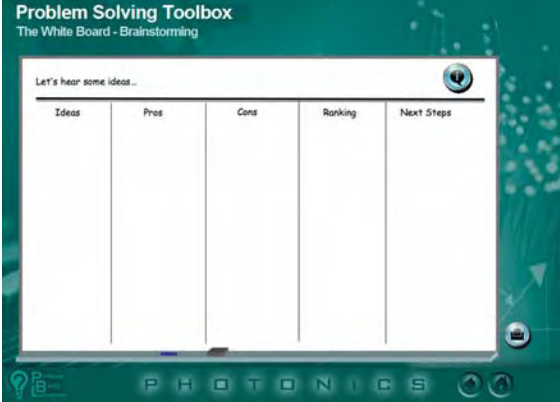
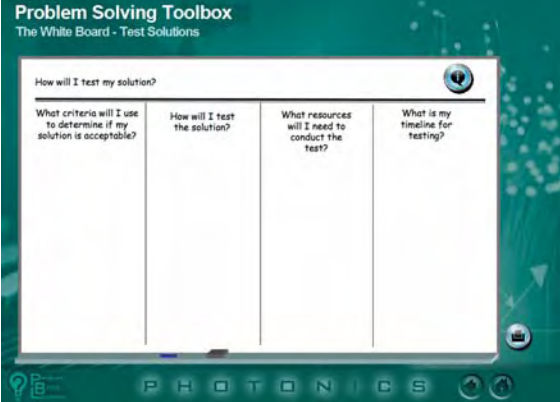

<p>Problem Solving Toolbox Slide 4</p> <p>The Brainstorming Whiteboard</p> <p>The Brainstorming Whiteboard is a tool designed to help students share the knowledge and information learned during the self-directed learning phase in a group effort to generate and evaluate alternative problem solutions. Ideas are exchanged without criticism or judgment. By expressing ideas and listening to what others say, students can gauge their own learning, increase their knowledge and understanding by integrating new information with prior knowledge, and converge on a problem solution that represents the collective knowledge of the group.</p>	
<p>Problem Solving Toolbox Slide 5</p> <p>The Test Solution Whiteboard</p> <p>The Test Solution Whiteboard is a tool designed the help students develop a viable test plan and procedure with performance benchmarks for validating their problem solution. If the test successfully validates the problem solution, a formal presentation is given to report the results. If the test does not successfully validate the proposed solution, the problem-solving process is repeated until an acceptable solution is developed.</p>	

Table 3 - PHOTON PBL Teacher Resources

Teacher Resources Page	
<p>The Teacher Resource Page contains four links:</p> <ol style="list-style-type: none">1. Technical Background - A technical tutorial for teachers to provide background knowledge related to the challenge.2. Assessment Strategies: A complete tutorial and instructions for assessing student content knowledge, conceptual knowledge, and problem solving ability.3. Case Studies: Examples of different implementation strategies compiled from two years of field-testing in HS and college level classrooms.4. Standards Alignment: PBL Challenges are aligned with National Science and Technological Literacy standards.	

APPENDIX

- Challenge Passwords
- The Whiteboards
- Final Challenge Report
- Final Challenge Report Scoring Rubric
- Concept Mapping Instructions
- Concept Map Scoping Rubric

I. PHOTON PBL: Problem Analysis Whiteboard

The first step in problem solving is to clearly and accurately define the problem. This is what we mean by *problem analysis*. To get started on a problem solution, you must understand the desired outcome, identify what you know, what you need to learn, and any special conditions that might apply. Only when you've clearly and accurately defined these parameters can you develop an effective plan for action. At this point, any preliminary ideas you may have for a solution can help guide the process.

What are we trying to accomplish?			
What do we know about the problem?	What do I need to learn?	Are there any special conditions that apply?	Any preliminary solution ideas?

II. Self-Directed Learning Whiteboard

Self-directed learning means taking responsibility for acquiring the knowledge and skills identified in the problem analysis phase needed to solve the problem at hand. Self-directed learning includes setting specific learning goals, identifying the necessary information and resources, and testing yourself to determine whether you have acquired the knowledge and skills needed to solve the problem.

What are my learning goals?			
Specifically, what do I need to learn?	What resources will I use?	How will I budget my time?	How will I know when I have achieved my learning objectives?

III. Brainstorming Whiteboard

Brainstorming solutions involves applying what you've learned during the self-directed learning phase in a group effort to generate possible solutions to the problem at hand. Ideas are exchanged without criticism or judgment. By expressing ideas and listening to what others say, you will be able to gauge your level understanding, increase your knowledge and understanding by integrating new information with prior knowledge, and converge on a problem solution that represents the collective knowledge of the group.

Let's hear some ideas...				
Ideas	Pros	Cons	Ranking	Next Steps

IV. Test Solution Whiteboard

Once a preliminary solution has been developed, you and your team must *test the solution* to see if it produces the desired outcome identified in the problem analysis phase. Testing your solution first requires developing a detailed test plan and procedure with specific performance benchmarks. *One very important characteristic of a good test plan is that someone of reasonable intelligence can follow your plan and replicate your results.* If your test results successfully validate your solution, a formal presentation is given to report your results. If your test results do not successfully validate your solution, the problem-solving process is repeated until an acceptable solution is developed.

How will I test my solution?			
What criteria will I use to determine if my solution is acceptable?	How will I test the solution?	What resources will I need to conduct the test?	What is my timeline for testing?

Photon PBL Problem Solving Rubric – Page 1

Challenge Title _____

Student Name(s) _____

Problem-Solving Task	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Problem Analysis	<ul style="list-style-type: none"> • Student clearly and precisely defines problem parameters and criteria for success • Student correctly identifies all relevant knowledge and skills needed to solve problem • Student accurately identifies all relevant problem constraints • Student generates one or more creative and viable solution possibilities 	<ul style="list-style-type: none"> • Student adequately defines problem parameters and criteria for success • Student correctly identifies most relevant knowledge and skills needed to solve problem • Student accurately identifies most relevant problem constraints • Student generates one or more potentially viable solutions 	<ul style="list-style-type: none"> • Student defines some problem parameters and criteria for success • Student correctly identifies some relevant knowledge and skills needed to solve problem • Student identifies some relevant problem constraints • Student generates one or more questionable solution possibilities 	<ul style="list-style-type: none"> • Student incorrectly defines problem parameters and criteria for success • Student incorrectly identifies relevant knowledge and skills needed to solve problem • Student incorrectly identifies problem constraints • Student generates solution possibilities that are either unrealistic or incorrect 	
Self-Directed Learning	<ul style="list-style-type: none"> • Student correctly articulates specific and appropriate learning objectives • Student correctly identifies all required instructional resources • Student has a clear and realistic plan for learning • Student has a clear and realistic plan for monitoring his/her comprehension 	<ul style="list-style-type: none"> • Student correctly articulates specific learning objectives • Student correctly identifies most required instructional resources • Student has an adequate plan for learning • Student has an adequate plan for monitoring his/her comprehension 	<ul style="list-style-type: none"> • Student articulates questionable learning objectives • Student correctly identifies some required instructional resources • Student has an a rudimentary plan for learning that needs to be more fully developed • Student has a rudimentary plan for monitoring his/her comprehension that needs to be more fully developed 	<ul style="list-style-type: none"> • Student articulates learning objectives that are irrelevant and/or incorrect • Student identifies instructional resources that are irrelevant and/or incorrect • Student has inadequate or no plan for learning • Student has inadequate or no plan for monitoring comprehension 	
Brainstorming	<ul style="list-style-type: none"> • Student generates numerous viable alternative solutions • Student demonstrate effective collaboration and teamwork skills • Student accurately and correctly identify valid pros and cons • Students precisely and methodically evaluate and rank alternative solutions • Students articulate a clear and concise plan of action for enacting their solution 	<ul style="list-style-type: none"> • Student generate numerous alternative solutions • Student demonstrates adequate collaboration and teamwork skills • Student identifies some valid pros and cons • Students adequately evaluate and rank alternative solutions • Students articulate an adequate plan of action for enacting their solution 	<ul style="list-style-type: none"> • Student generate some alternative solutions that need to be more thoroughly developed • Student demonstrates collaboration and teamwork skills that need refinement • Student identifies some pros and cons but needs to improve process • Students evaluate and rank alternative solutions but methods need improvement • Students articulate a plan of action for enacting their solution that needs refinement 	<ul style="list-style-type: none"> • Student generates inadequate or no alternative solutions • Student demonstrates poor collaboration and teamwork skills • Student either do not identify some pros and cons or do so incorrectly • Students do not evaluate and rank alternative solutions • Students articulate no plan of action for enacting their solution 	

Photon PBL Problem Solving Rubric – Page 2

Problem-Solving Task	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Test Solutions	<ul style="list-style-type: none"> • Test plan clearly and correctly addresses all solution criteria • Test plan has a well defined and realistic timeline • Testing methods and procedures are appropriate and valid • All testing resources are clearly identified and appropriate • Solution benchmarks are clearly identified and measurable 	<ul style="list-style-type: none"> • Test plan clearly and correctly addresses most solution criteria • Test plan has an adequate and realistic timeline • Testing methods and procedures are appropriate and valid • Most testing resources are identified and appropriate • Solution benchmarks are identified and mostly measurable 	<ul style="list-style-type: none"> • Test plan addresses some solution criteria • Test plan has a timeline that needs refinement • Testing methods and procedures are provided but need improvement • Testing resources need to be more clearly identified • Solution benchmarks are identified but need refinement 	<ul style="list-style-type: none"> • Test plan does not addresses solution criteria • Test plan does not have timeline • Testing methods and procedures are either not provided or are incorrect • Testing resources are not identified • Solution benchmarks are not identified 	
Solution Quality	<ul style="list-style-type: none"> • Solution clearly and effectively addresses all stated criteria and exceeds performance benchmarks • Solution represents a realistic and cost effective means of addressing problem • Solution is novel, creative and reflects exemplary problem solving and critical thinking skills • Solution can be easily replicated 	<ul style="list-style-type: none"> • Solution effectively addresses most stated criteria and meets most performance benchmarks • Solution represents a realistic means of addressing problem • Solution shows creativity and reflects good problem solving and critical thinking skills • Solution can be easily replicated with some effort 	<ul style="list-style-type: none"> • Solution addresses some stated criteria and meets some performance benchmarks • Solution represents a means of addressing the problem but needs improvement • Solution is shows marginal problem-solving and critical thinking skills • Solution can be replicated but with considerable effort 	<ul style="list-style-type: none"> • Solution does not address stated criteria and/or does not meet performance benchmarks • Solution represents an invalid or ineffective means of addressing the problem • Solution is shows poor problem solving and critical thinking skills • Solution cannot be replicated without major revisions 	
Comments:					Total Score

PHOTON PBL

Concept Mapping Instructions

Concept mapping is a graphical technique used to assess students' conceptual knowledge. While there are a number of different approaches available in the literature and on the Internet, we have adopted a modified version of the method employed by the VaNTH (Vanderbilt University, Northwestern University, University of Texas, and Harvard University) Engineering Research Center.

Concept maps can be created using an “open-ended” approach in which students generate and map their own list of concepts related to a particular topic, or using a more structured approach whereby the instructor provides students with a list of concepts to be mapped. In our approach, we provide students with the list of concepts related to a particular PBL challenge in order to limit variability. A complete list of main concepts and sample concepts maps for each PBL challenge is located in the “Teacher Resource” section of each PBL challenge.

How do I construct a concept map?

The following example illustrates how to instruct students to construct a concept map for the PhotoMachining Challenge.

Example

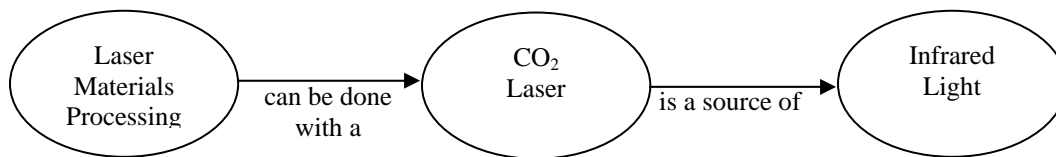
Problem: How do we strip a 50 um wire with a laser?

PhotoMachining Concepts

CO ₂ Laser	Wavelength	Lenses	Accuracy
Excimer Laser	Absorption	Mirrors	Tolerance
Ablation	Reflection	Mask	Wire Stripping
Irradiance	Infrared	Magnification	Ultraviolet
Beam Delivery			

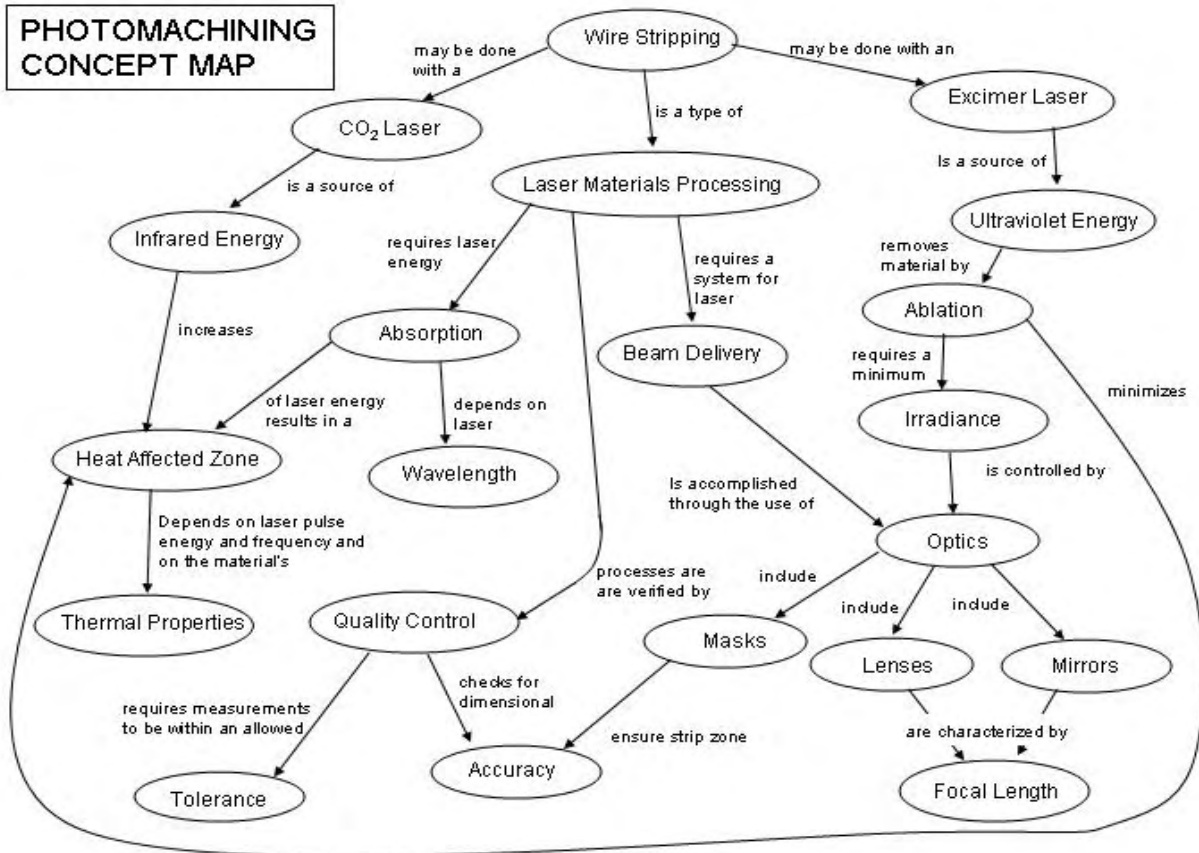
Instructions

1. From the list of concepts shown above, organize and group related concepts in a hierarchal fashion on a whiteboard or piece of paper.
2. Connect related concepts using lines with arrows that show the direction of the relationship
3. Label each line with words or short phrases that describe the relationship between the two concepts. **IMPORTANT:** Each relationship between any two concepts should form a complete proposition. For example:



Propositions generated:

- Laser materials processing can be done with a CO₂ laser.
 - CO₂ laser is a source of infrared light.
4. Examine the linkages to make sure each relationship forms a valid proposition.
 5. Rearrange and/or remove concepts to simplify and clarify the concept map
 6. When you are satisfied with your concept map, make sure it is NEAT and CLEAR and list each proposition formed on a separate sheet. (Instructor: See attached example).



Propositions Generated

1. Wire stripping is a type of laser materials processing.
2. Laser materials processing requires a system for laser beam delivery.
3. Beam delivery is accomplished through the use of optics.
4. Wire stripping may be done with a CO₂ laser.
5. A CO₂ laser is a source of infrared energy.
6. Infrared energy increases heat affected zone.
7. Wire stripping may be done with an excimer laser.
8. An excimer laser is a source of ultraviolet energy.
9. Ultraviolet energy removes material by ablation.
10. Ablation requires a minimum irradiance.
11. Ablation minimizes heat affected zone.
12. Irradiance is controlled by optics.
13. Optics include mirrors.
14. Optics include lenses.
15. Optics include masks.
16. Lenses and mirrors are characterized by focal length.
17. Masks ensure strip zone accuracy.
18. Laser materials processing requires laser energy absorption.
19. Absorption depends on laser wavelength.
20. Absorption of laser energy results in a heat affected zone.
21. Heat affected zone depends on laser pulse energy and frequency and on the material's thermal properties.
22. Laser materials processing processes are verified by quality control.
23. Quality control checks for dimensional accuracy.
24. Quality control requires measurements to be within an allowed tolerance.

Photon PBL Concept Map Scoring Rubric

Challenge Title _____

Student Name(s) _____

Assessment Criteria*	Excellent = 4	Good = 3	Fair = 2	Poor = 1	Score
Concept Validity (use only when concepts are not provided to students)	<ul style="list-style-type: none"> Student correctly identifies all relevant concepts and items related to the topic. 	<ul style="list-style-type: none"> Student correctly identifies most relevant concepts and items related to the topic 	<ul style="list-style-type: none"> Student correctly identifies some relevant concepts and items related to the topic 	<ul style="list-style-type: none"> Student correctly identifies few or no relevant concepts and items related to the topic 	
Proposition Validity	<ul style="list-style-type: none"> All propositions are complete and valid. Linking lines connect related terms and point in correct direction. Linking words accurately describe relationship between concepts. Student shows a deep understanding of the relationship between concepts. All or most concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Most propositions are complete and valid. Most linking lines connect properly. Most linking words accurately describe the relationship between concepts Student shows a good understanding of the relationship between concepts. Most concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Correct but incomplete propositions. Linking lines not always pointing in correct direction. Linking words are absent or don't clarify relationships between concepts. Student shows a partial understanding of the relationship between concepts. Some concepts are linked to more than one related concept. 	<ul style="list-style-type: none"> Few or no valid propositions. Linking lines do not point in correct direction. Linking words are absent or incorrectly identify relationships between concepts. Student shows a lack of understanding of the relationship between concepts. Some concepts are not linked to more than one related concept. 	
Presentation	<ul style="list-style-type: none"> Concept map is neat, clear, legible, and has easy to follow links. No spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is neat, clear, legible, and has easy to follow links. Has some spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is messy and has somewhat difficult to follow links. Has many spelling or grammatical errors. 	<ul style="list-style-type: none"> Concept map is sloppy and links are difficult or impossible to understand. Has many spelling or grammatical errors. 	
Comments:					Total Score

* Assessment criteria weighting is based on instructor discretion